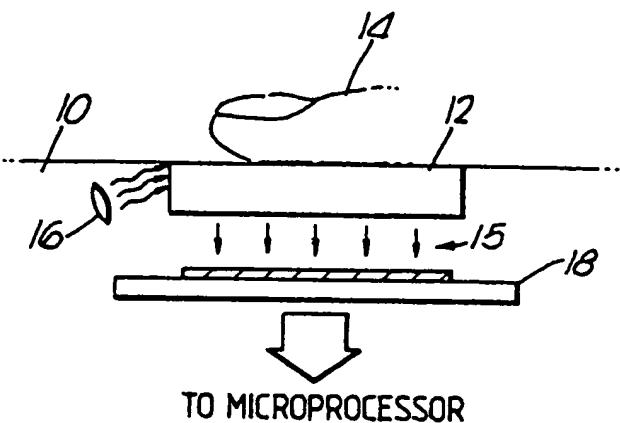


PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau



INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁴ : G07C 9/00		A1	(11) International Publication Number: WO 87/06378 (43) International Publication Date: 22 October 1987 (22.10.87)
<p>(21) International Application Number: PCT/GB87/00262 (22) International Filing Date: 21 April 1987 (21.04.87)</p> <p>(31) Priority Application Number: 8609620 (32) Priority Date: 19 April 1986 (19.04.86) (33) Priority Country: GB</p> <p>(71) Applicant (for all designated States except US): IMAGEPACK LIMITED [GB/GB]; Ludgate House, Fleet Street, London EC4A 2AB (GB).</p> <p>(72) Inventors; and (75) Inventors/Applicants (for US only) : WHEATLEY, Richard [GB/GB]; 31a Earith Road, Willingham, Cambridgeshire CB4 5LS (GB). WHEATLEY, Malcolm, Robert, Henry [GB/GB]; 5 Old Court Hall House, Godmanchester, Huntingdon, Cambridgeshire PE18 8HS (GB). STOTEN, Philip, Anthony [GB/GB]; 19 Horselow Street, Potton, Bedfordshire (GB).</p>		<p>(74) Agent: GODSILL, John, Kenneth; Haseltine Lake & Co., Hazlitt House, 28 Southampton Buildings, Chancery Lane, London WC2A 1AT (GB).</p> <p>(81) Designated States: AT (European patent), AU, BB, BE (European patent), BR, CH (European patent), DE (European patent), DK, FI, FR (European patent), GB, GB (European patent), HU, IT (European patent), JP, KP, KR, LK, LU (European patent), MC, NL (European patent), NO, RO, SE (European patent), SU, US.</p> <p>Published <i>With international search report.</i></p>	
<p>(54) Title: IDENTITY VERIFICATION</p> 			
<p>(57) Abstract</p> <p>A fingerprint verification technique involves the derivation of data from a fingerprint in the form of an ordered set of values relating to the number of ridges (or troughs) measured orthogonal to a line across an area of the fingerprint, at each of a plurality of positions along the line. The data is derived using a semiconductor imaging sensor (18) consisting of a two-dimensional array of image sensing elements. Each line of the imaging sensor is read out as a varying DC voltage which is compared with a reference value in thresholding circuitry (42). The digital signal produced by the thresholding circuitry is used to clock a counter (44) to obtain for each row of the array a count of the ridges (or troughs) in that row of the array.</p>			

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT Austria	FR France	ML Mali
AU Australia	GA Gabon	MR Mauritania
BB Barbados	GB United Kingdom	MW Malawi
BE Belgium	HU Hungary	NL Netherlands
BG Bulgaria	IT Italy	NO Norway
BJ Benin	JP Japan	RO Romania
BR Brazil	KP Democratic People's Republic of Korea	SD Sudan
CF Central African Republic	KR Republic of Korea	SE Sweden
CG Congo	LJ Liechtenstein	SN Senegal
CH Switzerland	LK Sri Lanka	SU Soviet Union
CM Cameroon	LU Luxembourg	TD Chad
DE Germany, Federal Republic of	MC Monaco	TG Togo
DK Denmark	MG Madagascar	US United States of America

-1-

1 TitleIDENTITY VERIFICATIONField of the invention

5 This invention relates to identity verification and in particular concerns a method and apparatus for encoding and storing information relating to fingerprints and a method and apparatus for verifying the identity of a person.

10

Background of the invention

15 There are various circumstances in which it is important or desirable to be able to verify the identity of a person, for example for security reasons or in financial transactions to reduce or eliminate credit card and cheque card fraud.

20 Fingerprints constitute a unique characteristic of an individual and fingerprint comparison provides a good basis for identity verification that is widely used by bodies such as the police. However, visual comparison of fingerprints is a skilled task which cannot be performed reliably by untrained personnel.

25 There have been proposed several systems utilising fingerprint identification. Generally the prior proposals are concerned either with the improvement of a fingerprint image for visual comparison (for example see US 3,975,711) or with the production of characteristic data from a representation of a fingerprint. In the 30 latter case, information from a fingerprint is obtained by scanning a fingertip or by providing an analogue or binary image of the fingertip. The image, or scanning output data, is processed to provide such characteristic data. In some prior proposals (for example US 4,210,899) 35 the characteristic data is the minutiae of a fingertip, the minutiae being the ends and bifurcations of ridges of a fingerprint.

-2-

1 In another prior proposal (WO 82/03286) papillary
line information is obtained by locating a reference
point, defining several reading circles and sequentially
deriving data from the reading circles to provide a bit
5 sequence representative of a particular fingerprint.

There are two associated problems common to the
above-mentioned systems, which to a large extent have
hindered the commercial application of the systems on a
wide scale. The first of these problems is the need to
10 locate a reference point for data derived from the
fingertip whose print is to be encoded. This is because
such data must be capable of being stored and
subsequently compared with similarly derived data for
verification purposes. Even with the assistance of known
15 mechanical and optical registering techniques, it is not
possible to ensure that a subsequently positioned
fingertip will be located in precisely the same position
relative to a scanner or imaging device as when the data
was originally derived. Therefore, a reference point
20 must be found at each encoding and verification step, and
this is not a trivial task for the characteristic data
types referred to above. If no reference point is
located, inaccuracies in use of the equipment will
result.

25 The second problem lies in the type of
characteristic data which is obtained. Such data
involves a detailed analysis of an image of the
fingerprint to determine such items as ridge depth,
trough depth, ridge ends, position etc.. This coupled
30 with the need for referencing, requires complex image
production and signal processing equipment to the extent
that the complexity and expense of such equipment
constitutes a bar to commercial applicability in a wide
sense. It is clear that, not only must the equipment for
35 production and processing of the data be complex, but
also that verification equipment for comparing stored
data with newly derived data for identification purposes

-3-

1 suffers from the same problems. One attempt at simplification in respect of the second problem has been proposed in US 3,231,861, where data is derived from a scan of a single line across a fingertip. Such data
5 includes the form of ridges and troughs, with their width, position and spacing. This proposal has stringent alignment requirements, and therefore is particularly prone to the first problem. A suggested solution in that case is the use of particular optical finger locating
10 means for mechanical registration.

A further disadvantage arising from prior proposals is that in cases where, between data derivation steps, a fingerprint is scratched or otherwise damaged, the equipment has no facility to cope. In US 3,231,861 a
15 rerun of the scan is suggested: in other cases the problem, which will inevitably occur in practice, is not addressed.

It is hence desirable to obviate or at least to mitigate the above-referenced problems in fingerprint
20 identification.

It is also desirable to provide a method and apparatus enabling a fingerprint verification technique to be put into effect simply and relatively cheaply.

25 Summary of the invention

According to one aspect of the invention there is provided a method of obtaining information from a fingerprint characterised by deriving from an area of the
30 fingerprint data relating to the number of ridges (or troughs), orthogonal to a line across the area, at each of a plurality of positions along the line.

By storing such derived data and comparing the stored data with similar data derived in similar manner
35 from the corresponding fingerprint of a person, the identity of the person can be verified.

Hence, in a further aspect the present invention

-4-

1 provides a method of verifying the identity of a person
by deriving data from their fingerprint in accordance
with the method defined above comparing such data with
similarly derived and previously stored data from the
5 fingerprint to be compared; and indicating the result of
the comparison step.

Preferably, a tolerance is provided such that, if
the two sets of information correspond to within a
prescribed degree of tolerance, the identity of the
10 person is verified, and an appropriate indication, e.g.
visual or audible, can be given.

It will be apparent that the invention is
applicable to prints from any finger or thumb of a
person. For brevity the term "fingerprint" is used to
15 cover both fingerprints and thumb prints, and any other
suitable characteristic skin configurations.

The present invention is based on the discovery by
the present inventors that such number versus position
information is sufficiently uniquely characteristic of a
20 fingerprint to enable accurate verification to be carried
out. As described below, in a preferred embodiment the
information is obtained and stored as a ridge (or trough)
count for each of plurality of extremely narrow strips
extending substantially perpendicular to said line.

25 In that preferred embodiment, such information is
derived as follows:

An image of the arrangement of ridges and troughs
of a fingerprint is conveniently produced by use of a
two-dimensional semiconductor imaging sensor array such
30 as a charge coupled device or MOS imaging sensor. Such
sensors comprise an array of image sensing elements
(photosites) in which each photosite accumulates a charge
which is directly proportional to the intensity of
incident light. MOS imaging sensors are at present
35 considered preferred since they can be manufactured more
reliably than existing charge coupled device technology
permits. Further, they have a simpler line read out

-5-

- 1 sequence more suited to application of the techniques of this embodiment of the present invention. The signal from the sensor is then processed by converting the charges into voltages and then applying voltage
- 5 thresholding (with voltages above a particular value being treated as one and those at or below the value being treated as zero). The thresholded signal can be used to produce a binary image of the pattern of ridges (represented by ones) and troughs (represented by zeroes)
- 10 from which the number information is derived, or can be used directly to produce number information.

Information representing the binary image, or the thresholded signal itself, is conveniently input to computer means such as a suitable microprocessor for

- 15 derivation of information in a suitable form for storage.

A suitable signal can also be derived using other known fingerprint imaging techniques as in the prior proposals discussed earlier: the only restriction is that it must be possible to derive a count of the number

- 20 of ridges (or troughs) in the relevant direction.

The present invention is particularly applicable to cases where storage space is limited and where it is not practicable to store a full representation of the binary image, i.e. an array of "ones" and "zeros". Thus,

- 25 the information is stored in the form of an ordered set of counts hereinafter referred to as graphical data because it is capable of being represented as one or more graphs representing the variation in ridge (or trough) density with position. Such a graph can be obtained from
- 30 an indication of the number of ridges (or troughs) in each row or column of the array by counting the number of transitions from zero to one for ridge count (or one to zero for trough count) within each row or column. This can be done by using the thresholded, binary signal for
- 35 each row or column of the array to clock a counter actuatable on either the trailing or leading edges of the transitions.

-6-

1 The shape of such a graph has been found by the
inventor, perhaps surprisingly, to be uniquely
characteristic of a particular fingerprint. Using known
statistical analysis techniques, the graph, or graphical
5 data representative thereof, can be represented by
various characteristic parameters derived therefrom, such
as peak value, tri-quartile value, median value, quartile
value etc of ridge (or trough) density or the area under
the graph etc. Sufficient information to characterise
10 the graph(s) (and hence fingerprint) to a desired degree
is hence calculated, for example using suitable
algorithms programmed into the computer. Subject to
storage space limitations, it is appropriate to derive
sufficient information to characterise a particular
15 fingerprint and distinguish from all others, without
being sensitive to normal variations in a particular
print e.g. due to dirt or damage such as cuts. A suitable
level of information and degree of correspondence in
matching to produce a satisfactory working system can be
20 determined experimentally.

The resulting information is converted into a
suitable form for storage.

The information is preferably stored in
machine-readable form, e.g. in magnetic form using
25 conventional encoding techniques. For instance, the
information may be encoded onto the magnetic stripe of a
conventional credit card.

In use during verification, stored information
relating to a fingerprint of a particular person is read
30 in suitable manner, e.g. using a conventional magnetic
reader in the case of magnetically stored information.
Similar information relating to the corresponding
fingerprint of the person whose identity is to be
verified is obtained in similar manner to that in which
35 the stored information was originally obtained. The two
sets of information are compared, conveniently using
computer means, and if they correspond to within a

1 prescribed degree of tolerance the identity of the person
is verified and may be indicated in any appropriate
manner.

The method should preferably be able to
5 accommodate or compensate for variations in the
positioning and orientation of the finger being examined
during verification, as it is highly unlikely that a
finger will be located in exactly the same position
10 relative to image-producing equipment during both storage
and verification steps. In embodiments using graphs or
graphical data derived therefrom, as described above,
variations in positioning and orientation can be
accommodated by manipulating the comparable graphs using
15 standard graph translation techniques, e.g. by suitable
programming of computer means, until the graphs are
aligned. For example, variations in positioning along
the length of the finger can be accommodated by use of
data relating to the area under a graph of ridge (or
trough) density variations in the longitudinal direction
20 with position across the width of the finger. Alignment
can be effected by manipulating the measured graph using
standard graph translation techniques until its integral
(representing the area under the graph) matches that of
the stored graph. Similarly, variations in positioning
25 across the width of the finger can be accommodated by use
of data relating to peak ridge (or trough) density, if
necessary. To eliminate the need for comprehensive graph
translation for comparison, means for mechanically
registering a finger can also be provided.

30 The invention is applicable in a range of
contexts, and lends itself well to use in verification of
credit cards and cheque cards, with data conveniently
being stored in magnetic form on the existing magnetic
stripe of such cards. The existing stripes allow up to
35 107 bytes of data to be stored, and storage may be
achieved using conventional encoding techniques. Data
stored in this way may be read by conventional card
reading

-8-

1 equipment.

It is also applicable to security systems for controlling entrance into a building, and for "clocking in" and "clocking out" of employees. In the latter case, 5 the clocking in device would include an imaging sensor and would only record the time of clocking in on production of a validation signal on comparing the data stored or the user's card and his fingerprint, to avoid one employee clocking in for several people by using 10 their cards.

The invention also includes within its scope apparatus for use in the methods.

Hence, in a further aspect, there is provided apparatus for encoding information for obtaining 15 information from a fingerprint characterised by:

means for deriving data relating to the number of ridges (or troughs) with respect to position along a dimension of the fingerprint.

20 The invention also provides apparatus for verifying the identity of a person as defined above and including means for comparing data so derived from a fingerprint of that person with data, similarly derived and previously stored, of the fingerprint to be compared; and means for indicating the result of the comparison.

25 For a better understanding of the present invention, and to show how the same may be carried into effect, reference will now be made, by way of example, to the accompanying drawings which illustrate an embodiment for use as a credit card checker.

30

Brief description of the drawings:

Figure 1 illustrates schematically apparatus for receiving image data from a fingerprint for encoding onto 35 the magnetic stripe of a credit card;

Figure 2 is a block diagram of circuitry used for production of density vs distance graphical data;

-9-

1 Figures 3b and 3c show the signals in the apparatus of Figure 2 in relation to a fingerprint pattern (Figure 3a);

5 Figure 4a illustrates schematically a sample thumbprint and Figures 4b and 4c show graphical information schematically representing data derived from a thumbprint but not necessarily corresponding to that of Figure 4a;

10 Figure 5 illustrates schematically credit card checker apparatus for verifying the identity of a person;

Figures 6a and 6b show two possible cases of vertical fingerprint misalignment during verification;

15 Figures 7a and 7b show two possible cases of horizontal fingerprint misalignment during verification;

Figures 8c and 8b show fingerprints and graphs for damaged or scratched fingerprints; and

Figures 9a to 9c are a side, end and plan view respective of a mechanical registration means for the apparatus of Figures 1 and 5.

20 Detailed description of the preferred embodiments

The apparatus illustrated in Figure 1 comprises a support 10 with a glass focusing plate 12 on which the pad of a finger 14, say the right hand thumb, of a person is located.

25 A light source 16 is located below the support 10, for side illumination of thumb 14 through plate 12. Reflected light 15 is directed to a semiconductor imaging sensor 18, such as a charge coupled device or MOS image sensor. Sensor 18 consists of a uniform two-dimensional array of image sensing elements (photosites), typically comprising 200 lines each with 250 photosites. When light falls onto such a photosite it accumulates a charge which is directly proportional to the intensity of the incident light. In use, the sensor 18 will thus build-up 30 an image representative of the arrangement of ridges and troughs of the illuminated thumbprint.

35 After an integration period, during which an image

-10-

1 of the fingerprint will be built up within the photosites
of the imaging sensor 18, each line of the imaging sensor
is read out as varying DC voltage. Figure 3b gives a
typical example of an output signal from the sensor for
5 the fingerprint variation of Figure 3a. The voltage
varies, depending on whether a fingerprint ridge or
trough was picked up by each of the photosites within
that line of the sensor array.

Figure 2 illustrates a system for converting the
10 video signal (Figure 3b) into a ridge-count (i.e. a count
of the number of fingerprint ridges present in that line
of the sensor array). The signal varies quite uniformly
around a central value which is the median between the
15 voltage at the centre of a ridge and that at the centre
of a trough. Using thresholding circuitry 42, the video
signal is converted into a digital signal (shown in
Figure 3c), which is used to clock a counter 44. The
thresholding circuitry is conventional, and essentially
determines whether the video signal level is above or
20 below a given value. By using the rising edge of the
digital signal from the thresholding circuitry 42, the
counter value will give a count of the number of ridges
within that particular line of the sensor's array.

Timing control circuitry 46 for the imaging sensor
25 indicates that a complete line of the sensor's image has
been output. This signals, via an interrupt port, a
microprocessor 48 to read the current value of the
counter 44 and then to reset the counter 44 ready to
acquire the ridge-count for the next line of the sensor
30 array. By acquiring the ridge-count for each line of the
sensor array a ridge-density graph of the form shown in
Figure 4b, that is in the form of an array of
ridge-counts with respect to position across the finger-
print can be built up. The shape of this graph is unique
35 for every fingerprint and can therefore be used to encode
a representation of the fingerprint onto the magnetic
strip of a plastic card for verification of a person's

-11-

1 identity at a later date using the same principle. If
further characterising information of the fingerprint is
required, a further graph representing ridge density
variation lengthwise of the fingerprint may be generated,
5 as shown in the graph of Figure 4c, and information
characterising that graph could also be stored on the
credit card.

While it would be possible to process the sensor
image to provide a binary matrix of ones and zeroes for
10 ridges and troughs, the limitation on data storage space
available on the magnetic stripe using such standard
encoding rules out the storage of such a matrix: the
current standard used for encoding data onto the magnetic
stripes of credit cards (International Standard
15 Organization standard 3) allows up to 107 bytes of data
to be stored on a standard magnetic stripe. However, the
production and storage of a complete matrix may be
appropriate in some circumstances.

The shape of graph of Figure 4b is far simpler to
20 process than a vast array of binary data. With an
imaging sensor comprising 200 rows each containing 250
photosites, this will give an accurate graph for a
typical thumbprint which has up to 50 ridges horizontally
and vertically.

25 Due to the limited amount of storage available on
the magnetic stripes, it may not be appropriate to store
the ridge density graph in its entirety.

In this case, the data can be compressed as
follows:

30 The points a through g on the horizontal axis of
the graph of Figure 4b are seven points which could be
used to characterise the ridge density graph. Point d
corresponds to the line number within the sensor array at
35 which the maximum ridge count to both sides of the peak
value were found. Similarly b and f are at half of the
maximum ridge count and a and g are at a quarter of the
maximum ridge count.

-12-

1 Values to both sides of the peak are calculated since it is highly unlikely that the graph will be symmetrical.

5 From the seven points a through g characterising values can be calculated to characterise the shape of the graph as follows:

1. The number of sensor array lines between points a and b.
- 10 2. The number of sensor array lines between points b and c.
3. The number of sensor array lines between points c and d.
- 15 4. The number of sensor array lines between points d and e.
5. The number of sensor array lines between points e and f.
- 20 6. The number of sensor array lines between points f and g.

20 Two other values which may be required are the actual peak ridge count and the area under the curve above the quarter peak ridge count: these two values will be used as described later when adjusting the graph 25 obtained from the card bearer's fingerprint for verification.

30 To minimise the amount of storage required for these eight characteristics, the values are stored as binary coded hexadecimal numbers using Track 1 on the card's magnetic stripe (this is because the American National Standards Institution specification only allows the storage of numeric characters on Track 2).

35 Each of the six characteristic values can be stored as a two character hexadecimal number which allows such characteristic values up to 255 (hexadecimal FF). The peak ridge count characteristic is again stored as a two character hexadecimal number, allowing a peak count

-13-

1 up to 255. The integral under the graph is stored as a four character hexadecimal number, giving a maximum value of 65535 (hexadecimal FFFF).

5 Using the above method, the graph characteristics are stored using only 18 characters on track 1 which still leaves sufficient storage space for additional data if it is determined in any particular case that using seven points a through g along the horizontal axis of the graph is insufficient for the required level of accuracy.

10 Figure 5 illustrates credit card checker apparatus as used at a point of sale (or entrance into a building for example) for verifying the identity of a user by deriving information from the corresponding thumbprint of the user and checking it against information stored on 15 the magnetic stripe of the user's card.

20 The apparatus comprises a thumbprint reader apparatus corresponding to the apparatus of Figure 1 and comprising a support 20, glass focusing plate 22, light source 24 and semiconductor imaging sensor 26. A representation of the fingerprint of the user's right thumb 28 is produced in exactly the same way as described in connection with Figure 1, and the information is fed via interface bus 30 to a control unit 32. The apparatus further comprises a conventional card reader 34 arranged 25 to read information stored on the magnetic stripe 36 of credit card 38 in conventional manner. Encoded data read by reader 34 is also fed via interface bus 30 to control unit 32.

30 When a person presents a card, he/she will be required to place a finger onto the glass plate 22 and a ridge density graph will be acquired as previously detailed. The encoded data will also be read from the magnetic stripe of the card. The control unit 32 will then compare the newly acquired graphical data against 35 that read from the card, using conventional comparison techniques.

The data stored on the plastic card represents

-14-

- 1 that section of the encoded ridge density graph which is above the quarter peak ridge count line on the graph constructed for encoding onto the card. For this reason, the newly acquired graph is adjusted vertically so that
- 5 the distance between the points where it crosses the horizontal axis is equal to the sum of the six horizontal scale characteristic values stored on the card (i.e. numbers corresponding to the distance between points a and g in Figure 4b). This is a simple process and is
- 10 performed by successively decrementing all elements of the number/distance memory array stored on the card which represents the ridge density graph.

Once the newly acquired graph has been adjusted, the peak value, integral under the curve and the six distances between points on the horizontal axis of the graph are calculated and are then compared with the characteristics encoded on the magnetic stripe of the card with an allowable margin of error, preferably determined by experiment to suit the particular application. If both sets of graphical data match, then the identity of the card bearer has been verified and some audible or visual indication of this fact is given to the user by an indicator 43.

Clearly, the position of the finger when the graph characteristics data was encoded onto the card and the position of the finger of the person being verified may be different, therefore the newly acquired graph will have to be adjusted to line it up with the graph represented by the encoded data.

Figures 6a to 6b show two possible effects on the ridge density graph caused by the finger being displaced vertically compared to the position of the finger at the time when the data was encoded onto the card. In Figures 6a to 7b the recently acquired graph is shown with a broken line and the previously stored graph is shown as a full line.

Figure 6a shows the effect of the finger being

-15-

1 moved so that there is more of the finger above the
sensor than at the time of encoding. This graph can
still be used to verify the fingerprint. The whole graph
5 is shifted down the vertical axis until the distance
between points where it meets the horizontal axis equals
the distance between points a and g of Figure 4b as
described above.

10 Figure 6b shows the effect of less of the finger
being above the sensor. The graph shown in this case has
been shifted down the vertical axis so far that the
distance between the points where it meets the horizontal
axis is less than the distance between quarter peak value
15 points of the graph data encoded on the card. In some
applications it may be determined that there is
insufficient data in this case for the stored graph to be
used to validate the newly acquired fingerprint. If the
vertical displacement of the graph had not reached the
20 point where the horizontal axis crossing points were
within the marked bounds then the graph could still be
used in most cases.

Figures 7a and 7b show two possible effects on the
ridge-density graph caused by the finger being displaced
laterally compared to the position at the time when the
data was encoded onto the card. The ridge count drops to
25 zero abruptly due to part of the finger being shifted
outside the field of the imaging sensor.

The graph shown in Figure 7a can still be used in
the verification since the lateral displacement has not
affected the shape of the graph above the quarter peak
30 value of the graph encoded on the card and since the
distances between horizontal axis points of the graph
have been stored on the card as opposed to actual
horizontal axis values.

35 The graph shown in Figure 7b is not suitable for
verification in the particular embodiment described since
the shape of the graph above the quarter peak value has
been affected by the displacement of the finger.

-16-

1 In all cases where the apparatus decides that the newly acquired graph will not be used in the verification process, some kind of warning e.g. audible or visual should be given to the user.

5 As explained above, the control unit 32 is programmed to accommodate variations in the positioning and orientation of the thumb relative to the sensor 18 during verification and storage steps by manipulation of comparable graphs using standard graph translation
10 techniques. It should also be possible to account for variations in positioning along the length of the thumb by use of data relating to the area under the graph by translating two graphs until their integrals are equal.

15 The verification apparatus is easy to use and does not require the use of skilled operators. Indeed, the apparatus may be designed for use by the card holder without requiring interaction from staff at the point of sale. The staff need simply note and react appropriately to the signal indicating successful validation, or
20 otherwise.

25 So far, it has been assumed that during the period between the time at which the bearer's fingerprint was encoded onto the magnetic stripe of the card and the time at which the bearer's fingerprint is being verified, the bearer has not damaged his/her fingerprint by, for example, scratching it. In the case of the finger being scratched, the shape of the ridge density graph will be changed.

30 Figure 8a shows an example of a fingerprint with a grossly exaggerated vertical scratch, and a ridge density graph showing the effect that that scratch would have on the shape of the graph. This situation can be quite easily recognised by control software by looking for a translation of the ridge density graph down the vertical
35 axis between two sensor array line numbers which correspond to the limits of the scratch. The effect on the ridge density graph would be remedied by adjusting

- 1 the elements of the array representing the ridge density graph which have been affected by the scratch, extrapolating from the slope of the graph to either side of the trough in the graph to construct a graph shape
- 5 which would represent the ridge density of the fingerprint without the scratch. Similarly, if at the time that the fingerprint is being encoded onto the card, the finger has such a vertical scratch, the acquired graph would be adjusted in a similar manner to counter
- 10 the effect of that scratch before the ridge density graph is encoded onto the card.

Figure 8b gives an example of a fingerprint with a grossly exaggerated horizontal scratch and a ridge density graph showing the effect that that scratch would have on the shape of the graph. This situation can be quite easily recognised by control software due to the sharp drop in ridge count at the left hand end of the scratch, scanning the graph from the left to right along with the sharp increase in ridge count corresponding to the right hand end of the scratch. The elements of the array which represent the graph between these two points would be adjusted to counter the effect of the scratch. Similarly, if at the time when the graph representation is being encoded onto the card, such a scratch is recognised, then the graph would be adjusted before its representation is encoded onto the card.

Scratches which are not in either the horizontal or vertical planes would have an effect on the shape of the graph which is a mixture of the cases shown in

- 30 Figures 8a and 8b and would be countered by performing adjustments of both cases given above.

It should be noted that unless the scratch is fairly substantial, the effect that it has on the ridge density graph will be minimal.

- 35 Both the encoder and the verification units can be constructed on a single circuit board which will also hold the microprocessor control unit, imaging sensor with

-18-

1 associated timing and drive circuits and the interface
circuits required for the magnetic strip reader/encoder.
The units may be housed in a single casing with just the
glass plate 20 on which the finger will be placed, a
5 reader/encoder slot through which the card will be passed
and a form of pass/fail indicator 43 externally visible.
Each unit will normally be in an inactive state and could
be activated by the plastic card being passed through the
reader/encoder slot at which stage a verification of the
10 bearer's fingerprint will be made.

Figures 9a, 9b and 9c show one form of sensing
unit which includes means for mechanically registering a
finger whose print is to be sensed, in order to align as
far as is possible fingerprint data obtained during
15 verification with that obtained during encoding, so as to
reduce the amount of software manipulation of the graph
data.

Figures 9a and 9b are a side and end view
respectively of a sensing apparatus with mechanical
20 registration and show the support 20 for the glass
focusing plate 12 (12 in Figure 1 and 22 in Figure 5). A
finger receiving member 50 has a fingertip receiving
notch 54 (Figure 9c) against which a fingertip is placed
with the finger over the glass plate 12. The fingertip
25 receiving member 50 is T shaped in end view (Figure 9b)
and is slidably mounted with respect to the support 20 by
grooves 56 formed in the sides of the member receiving
angled pieces 58 screwed to the support 20 for the glass
plate 12. It will be appreciated that any sliding
30 arrangement will suffice. The apparatus also includes an
abutment support 60 carrying a spring 62 and a
microswitch 64. The fingertip receiving member carries
an actuator 66 for the microswitch 64. In use, the
35 fingertip receiving member 50 is pushed, against the
action of spring 62 in its final stages, by a fingertip
until the actuator 66 activates the microswitch 64 to
indicate alignment and trigger commencement of scanning

1 by the sensor array (Figure 1). Although it is not shown in the drawings, a heat sensor could be provided for alignment of the finger in a horizontal sense (across the finger), to actuate the unit on sensing heat from the
5 finger to a certain level.

One application is to check identity at entrances into areas such as football grounds. In this way, the identity of previously known vandals would be indicated by comparison with previously stored data, and
10 access denied. Alternatively, positive verification, for example on the production of magnetic stripe cards from club members, could be carried out.

The invention has been described above in relation to encoding data onto magnetic stripe cards. Of course,
15 the encoding step has a far wider application. For example, it would be possible, where the system is to be used for security in a building such as a hotel to store the ridge density graphical data in its entirety in a central computer. Each authorised person could then be
20 issued with a card merely carrying information relating to a memory location in the central computer. The sensing unit could then transmit, during verification, the complete set of graphic data obtained for a full comparison within the central computer with the data
25 stored at that memory location. This embodiment effectively involves the transfer of the comparison step from a microprocessor at the sensing unit to a larger computer.

Embodiments of the invention are also applicable
30 at passport control centres, where fingerprint information provides fuller evidence that the bearer of the passport is truly authorised.

Another application is for the currently used so-called "credit card" safes such as that manufactured
35 under the trade name "Panther minisafe", which are operated with standard credit cards. Such safes can only be opened using the magnetic stripe card with which they were closed, and the fingerprint verification technique would provide extra security here.

-20-

1 CLAIMS:

1. A method of obtaining information from a fingerprint characterised by deriving from an area of the 5 fingerprint data relating to the number of ridges (or troughs), orthogonal to a line across the area, at each of a plurality of positions along the line.
2. A method as claimed in claim 1, in which the 10 number of ridges (or troughs) in a direction lengthwise of the fingerprint is derived at a plurality of positions across the fingerprint.
3. A method as claimed in claim 1 or 2 in which the 15 number of ridges (or troughs) in a direction across the fingerprint is derived with respect to a plurality of positions lengthwise of the fingerprint.
4. A method as claimed in any preceding claim characterised by using a sensing device to produce, for each of the plurality of positions, a signal related in magnitude to the arrangement of ridges and troughs 20 orthogonal to that line; comparing, for each position, the signal so produced with a reference value to obtain a signal for that position which varies between two values; counting the number of changes between the two values in the signal so obtained to derive a count of the number of 25 ridges (or troughs) corresponding to that position.
5. A method as claimed in claim 4, wherein the sensing device comprises a two-dimensional array of sensing regions.
6. A method according to any preceding claim in which 30 the data is derived as an ordered set of values.
7. A method as claimed in claim 6 in which one or more of the following items of data is derived:
 - a) the maximum number of ridges (or troughs) and the position where it occurs;
 - 35 b) the number of ridges (or troughs) corresponding to selected fractions (such as one quarter, one half or three quarters) of the maximum number and the

-21-

- 1 position where they occur;
 - c) the distance between the positions referred to in a) and b);
 - d) the area under a graphical representation of
- 5 the data as ridge (or trough) number against position;
- 10 e) the number and position at selected coordinate points of such a graphical representation.
- 15 8. A method of verifying a person's identity characterised by: deriving data from that person's fingerprint in accordance with the method of any preceding claim; comparing such data with similarly derived and previously stored data from the fingerprint to be compared; and indicating the result of the comparison step.
- 20 9. Apparatus for obtaining information from a fingerprint characterised by:
means for deriving, from an area of the fingerprint, data relating to the number of ridges (or troughs), orthogonal to a line across the area, at each of a plurality of positions along the line.
- 25 10. Apparatus as claimed in claim 9, wherein said means comprises: an image sensing device capable of producing for each position of the area a signal related in magnitude to the arrangement of ridges and troughs orthogonal to that line; means for comparing for each position the signal so produced with a reference value to obtain a signal for that position which varies between two values; and a counter for counting the number of changes between the two values in that signal to derive a
- 30 30 count of the number of ridges (or troughs) corresponding to that position.
11. Apparatus as claimed in claim 10, wherein the sensing device comprises a two-dimensional array of sensing regions.
- 35 12. Apparatus as claimed in claim 9, 10 or 11 including means for deriving said data as an ordered set of values of ridge (or trough) count with respect to

-22-

1 position.

13. Apparatus as claimed in any of claims 9 to 12 which includes processing means for processing the derived data to produce items of data, said items being
5 one or more of the following:

a) the maximum number of ridges (or troughs) and the position where it occurs;

b) the number of ridges (or troughs) corresponding to selected fractions (such as one quarter,
10 one half or three quarters) of the maximum number and the position where they occur;

c) the distance between the positions referred to in a) or b);

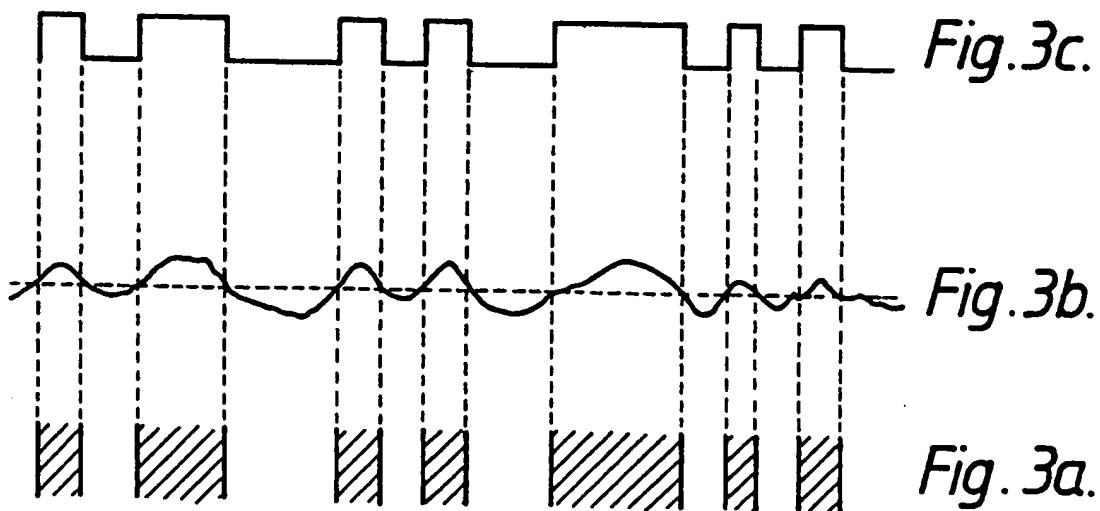
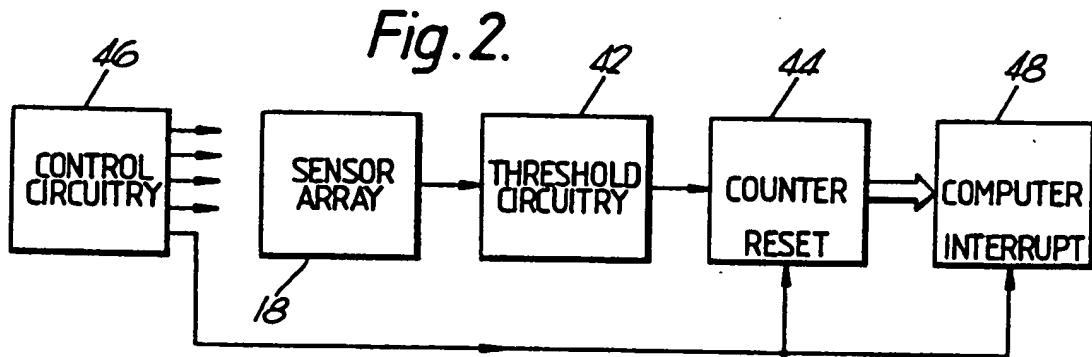
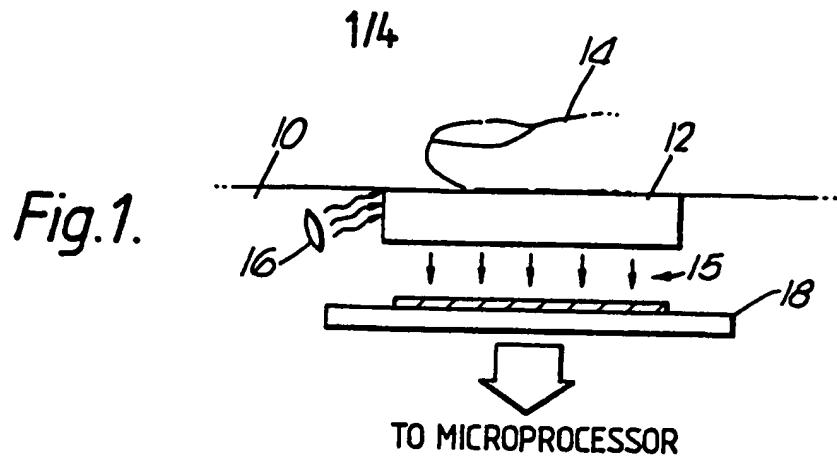
d) the area under a graphical representation of
15 the data as ridge (or trough) number against position;

e) the number and position at selected coordinate points of such a graphical representation.

14. Apparatus as claimed in any of claims 9 to 13, for verifying the identity of a person, which includes:
20 means for comparing data so derived from a fingerprint of that person with data, similarly derived and previously stored, of the fingerprint to be compared; and means for indicating the result of the comparison.

15. Apparatus as claimed in claims 13 and 14, in which
25 the processing means is capable of transforming two sets of such values representing respectively data derived from a fingerprint of a person whose identity is to be verified and previously stored data for comparison one with the other when the derived data and stored data do
30 not correspond due to differences in the area of the fingerprints from which the data is derived.

16. Apparatus as claimed in any of claims 8 to 13 which includes means for mechanically registering a fingerpad, whose fingerprint is to be sensed, with an
35 image sensing device of the apparatus.



2/4

Fig. 4a.

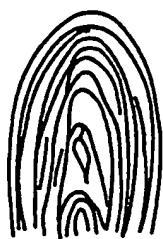


Fig. 4b.

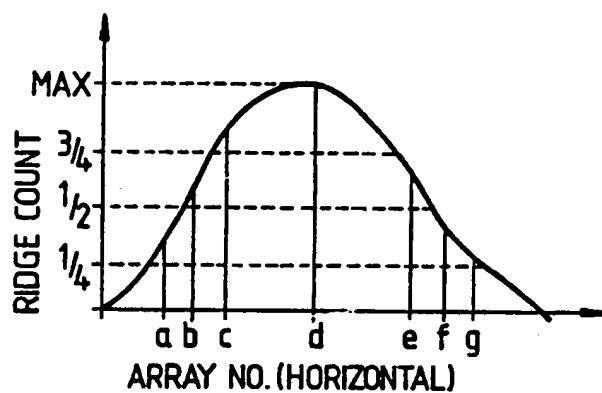


Fig. 4c.

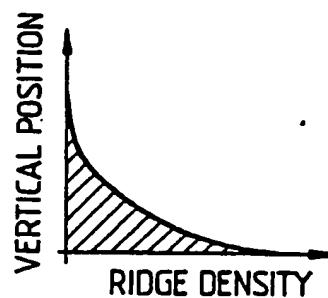
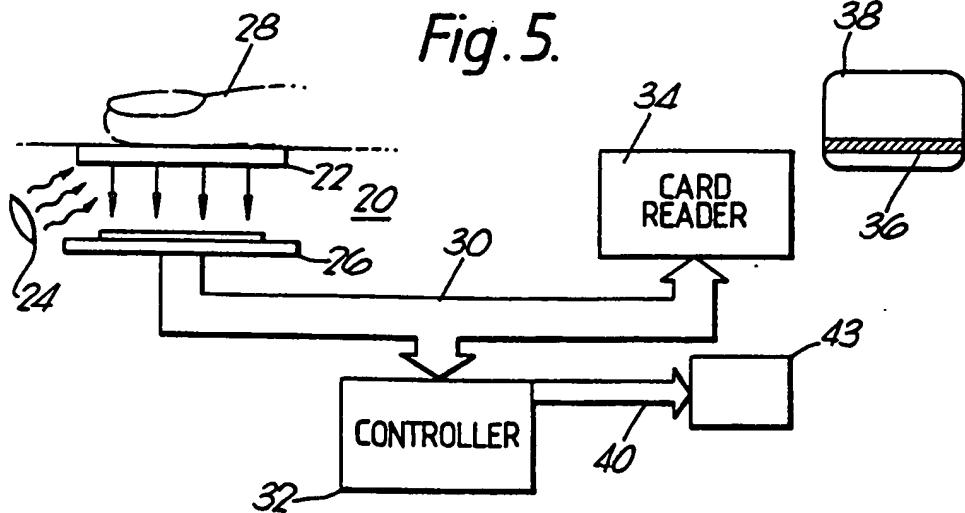


Fig. 5.



3/4

Fig. 6a.

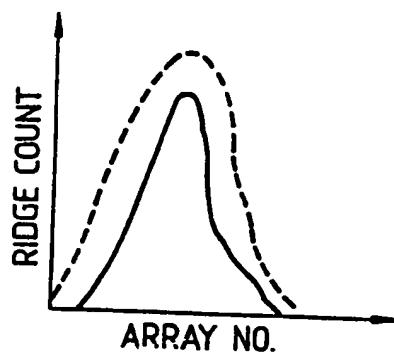


Fig. 6b.

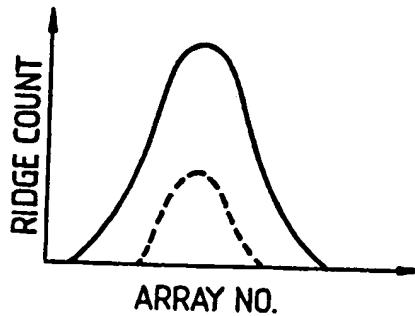


Fig. 7a.

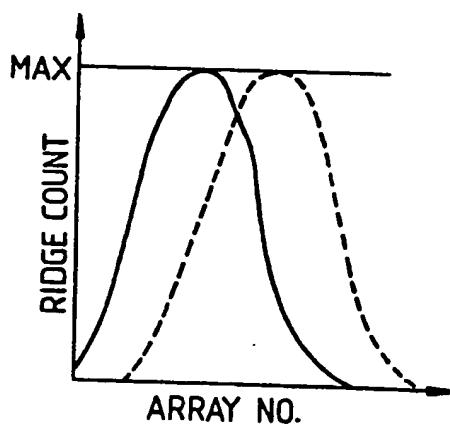
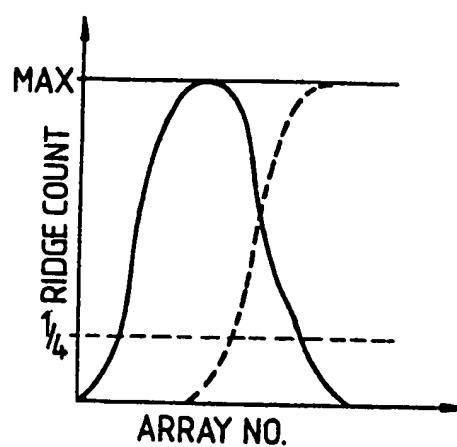


Fig. 7b.



4/4

Fig. 8a.

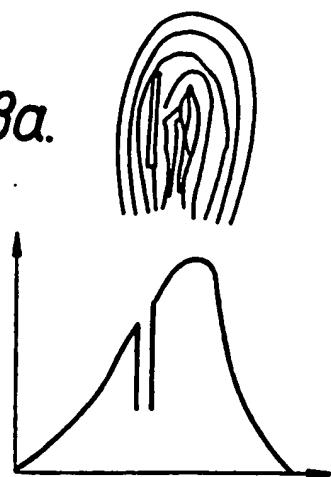


Fig. 8b.



Fig. 9a.

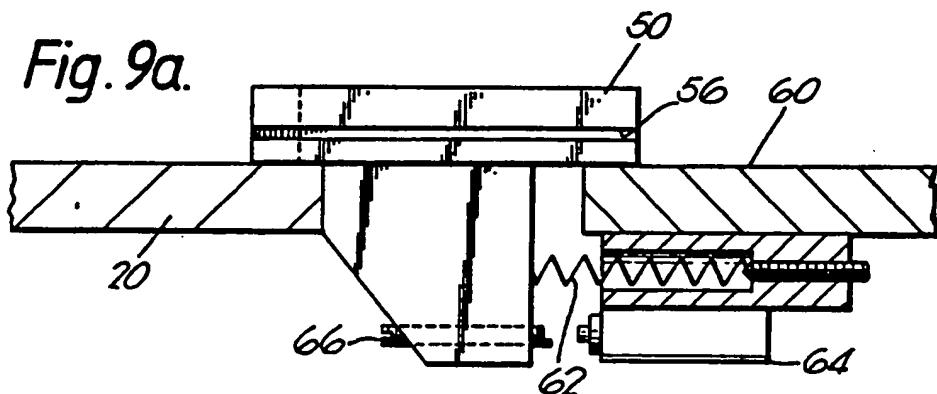


Fig. 9b.

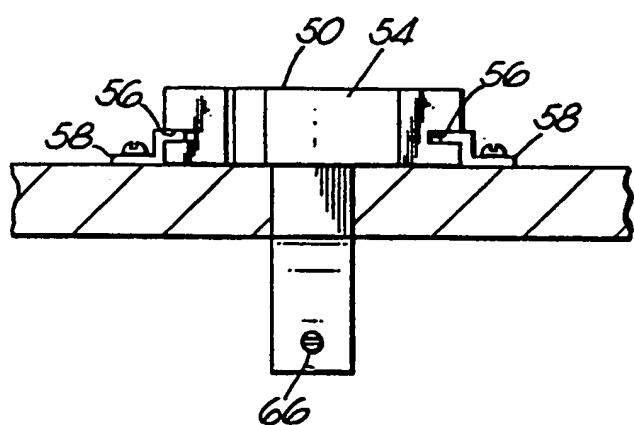
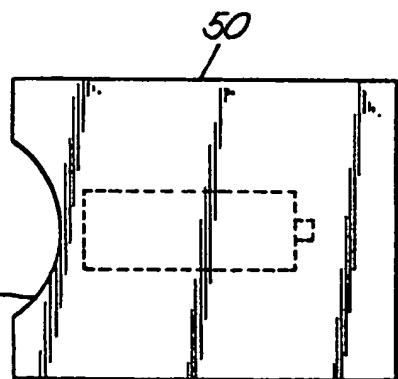


Fig. 9c.



INTERNATIONAL SEARCH REPORT

International Application No. PCT/GB 87/00262

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) ⁶

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC⁴ : G 07 C 9/00

II. FIELDS SEARCHED

Classification System	Minimum Documentation Searched ⁷	
	Classification Symbols	
IPC ⁴	G 07 C; A 61 B	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁸		

III. DOCUMENTS CONSIDERED TO BE RELEVANT⁹

Category ¹⁰	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³
X	EP, A, 0169496 (NEC) 29 January 1986 see abstract; page 2, line 23 - page 3, line 18; page 6, line 11 - page 10, line 4; page 11, line 1 - page 12, line 25; figures	1,9
A	--	2-8,10-14
X	EP, A, 0159037 (NEC) 23 October 1985 see abstract; page 2, line 13 - page 3, line 6; page 8, line 12 - page 10, line 26; figures	1,8,9
A	--	4,5,7,10-12,14,15
X	GB, A, 2050026 (NEC) 31 December 1980 see abstract; page 1, lines 43-103; page 2, line 89 - page 3, line 61; claims; figures	1,9
A	--	4-8,11-13
X	IBM Technical Disclosure Bulletin, volume 18, no. 3, August 1975, (New York, US),	./.

* Special categories of cited documents: ¹⁰

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the International filing date
- "L" document which may throw doubt on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the International filing date but later than the priority date claimed

"T" later document published after the International filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"A" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search

10th July 1987

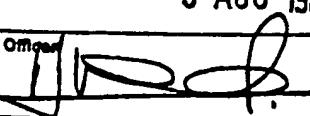
Date of Mailing of this International Search Report

- 5 AUG 1987

International Searching Authority

EUROPEAN PATENT OFFICE

Signature of Authorized Officer

M. VAN MOL 

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
	W.J. Deerhake et al.: "Fingerprint verification method", pages 888,889 see the whole document --	1,9
A	US, A, 4246568 (PETERSON) 20 January 1981 see column 2, line 14 - column 3, line 43; figures --	1,4-11,14, 15
A	US, A, 4186378 (MOULTON) 29 January 1980 see column 1, line 40 - column 2, line 32; claims; figures --	1,4-6,8-11, 14
A	WO, A, 82/03286 (LÖFBERG) 30 September 1982 see abstract; page 5, line 23 - page 7, line 16; page 10, line 8 - page 11, line 8; page 12, line 20 - page 16, line 16; figures cited in the application -----	1,4-6,8-10, 14

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON

INTERNATIONAL APPLICATION NO. PCT/GB 87/00262 (SA 16950)

This Annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 20/07/87

The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP-A- 0169496	29/01/86	JP-A- 61043379 JP-A- 61043380 JP-A- 61043381 JP-A- 61059574 JP-A- 61059580 JP-A- 61028175 US-A- 4663211	01/03/86 01/03/86 01/03/86 27/03/86 27/03/86 07/02/86 05/05/87
EP-A- 0159037	23/10/85	JP-A- 60221879 JP-A- 60221880 JP-A- 60221881 JP-A- 60221882 JP-A- 60221883	06/11/85 06/11/85 06/11/85 06/11/85 06/11/85
GB-A- 2050026	31/12/80	JP-A- 55138174 US-A- 4310827	28/10/80 12/01/82
US-A- 4246568	20/01/81	None	
US-A- 4186378	29/01/80	NL-A- 7806835 FR-A, B 2398351 DE-A, C 2831582 JP-A- 54052428 GB-A- 1601987 CA-A- 1121914	23/01/79 16/02/79 01/02/79 25/04/79 04/11/81 13/04/82
WO-A- 8203286	30/09/82	SE-A- 8101707 SE-B- 425704 AU-A- 8273682 EP-A, B 0085680 US-A- 4582985	19/09/82 25/10/82 06/10/82 17/08/83 15/04/86

For more details about this annex :
see Official Journal of the European Patent Office, No. 12/82

**This Page is Inserted by IFW Indexing and Scanning
Operations and is not part of the Official Record**

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- BLACK BORDERS**
- IMAGE CUT OFF AT TOP, BOTTOM OR SIDES**
- FADED TEXT OR DRAWING**
- BLURRED OR ILLEGIBLE TEXT OR DRAWING**
- SKEWED/SLANTED IMAGES**
- COLOR OR BLACK AND WHITE PHOTOGRAPHS**
- GRAY SCALE DOCUMENTS**
- LINES OR MARKS ON ORIGINAL DOCUMENT**
- REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY**
- OTHER:** _____

IMAGES ARE BEST AVAILABLE COPY.

As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.